The Solar Spectrometer

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1. Design

The solar spectrometer uses diffraction gratings, so its operation is governed by the grating equation

$$m = \sigma(\sin\alpha + \sin\beta)$$

where α is the angle of incidence, β is the angle of diffraction. The groove spacing is σ, the wavelength is and m is the order of interference.

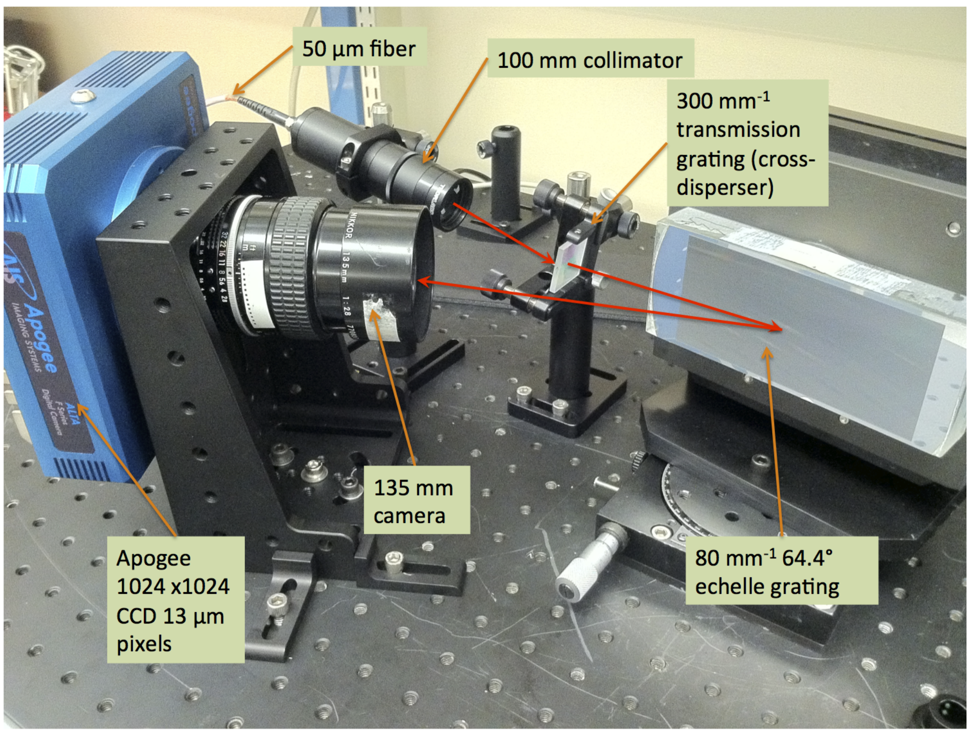

Figure 1: The solar spectrometer.

The solar spectrometer uses an “echelle” grating to provide high spectral resolving power $(R = /\Delta.)$ Echelle gratings are characterized by low groove densities; $1/\sigma$ = 80 mm^{-1} in this case. The corresponding groove separation is large (σ = 12.5 μm) as is the corresponding order of interference $(m \simeq 30$ at 600 nm.) The resultant free spectral range, $\Delta = /m$, is about 20 nm, which means that adjacent spectral regions separated by only 20 nm will overlap (same value of β.)

There are several ways to deal with overlapping orders. For example, a narrow bandpass optical filter ($\Delta \simeq 20$ nm) will exclude all but a single order of interference. Our solar spectrometer uses a different approach—it employs two gratings: an echelle grating that provides the high spectral resolving power ($R = /\Delta \approx 10,000$) and a second, lower dispersion ($1/\sigma$ = 300 mm^{-1}) grating that works in its first order to spatially separates the echelle diffraction orders on the CCD. This second grating is known as the cross disperser. The grooves of the two gratings are oriented so that they are approximately perpendicular and the resultant dispersion directions of the echelle and the cross disperser are nearly orthogonal.

2. Operation

Even though the spectrometer has two gratings, no adjustments are necessary for regular operation (with the possible exception of occasional focus checks.)

To collect data with the spectrograph you need to first start the NoMachine remote desktop software on you UG Lab workstation. When this is running you can launch the MaximDL application which controls the APOGEE CCD. The steps are (see Fig. 2):

1. Turn on the CCD via the web-controlled power strip (see below);
2. Launch the MaximDL application from the Windows 8 desktop;
3. Select the “Camera Control” window from the row of icons;
4. Choose the “Setup tab” from the Camera Control window;
5. Click “Connect”;
6. Turn on the cooler; and,
7. Wait a few minutes for the CCD to reach operating temperature.

To shut down the CCD when you are done:

1. Select the Camera Control window from the row of icons;
2. Choose the “Setup tab” from the Camera Control window;
3. Turn off the cooler;
4. Click “Disconnect”;
5. Quit MaximDL; and,
6. Turn off the CCD via the web-controlled power strip (and any calibration lamps too.)

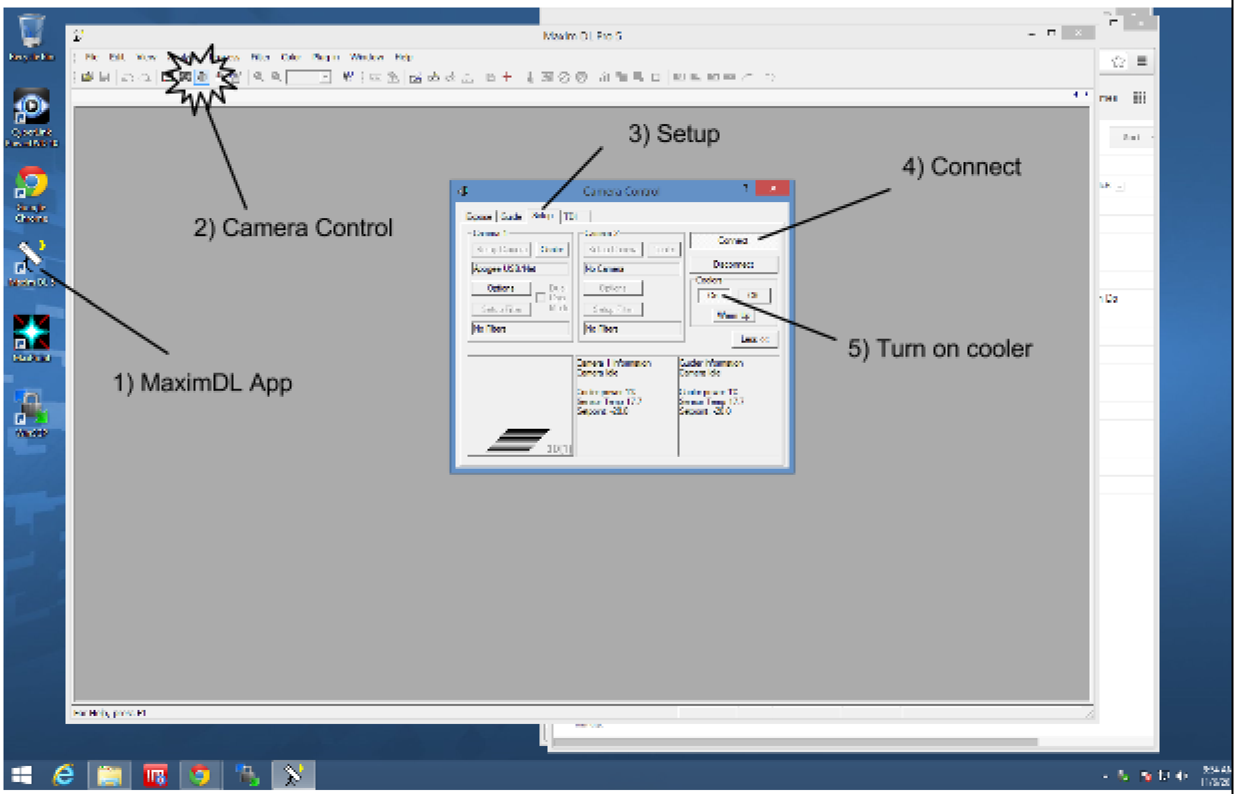

Figure 2: The Windows 8 desktop showing the MaximDL application and the sequence of actions required to connect to the Apogee CCD and turn on the cooler. When you are done with the CCD reverse the order, starting by turning the CCD cooler off.

To take a CCD exposure, select the “Expose” tab, set an exposure time (≥ 3ms), make sure that the type of exposure is set to “Single”. When the exposure is complete a window with pop up displaying the new image. Fig. 3 shows tools you can use to judge if the exposure is satisfactory (pixel statistics and row plots.)

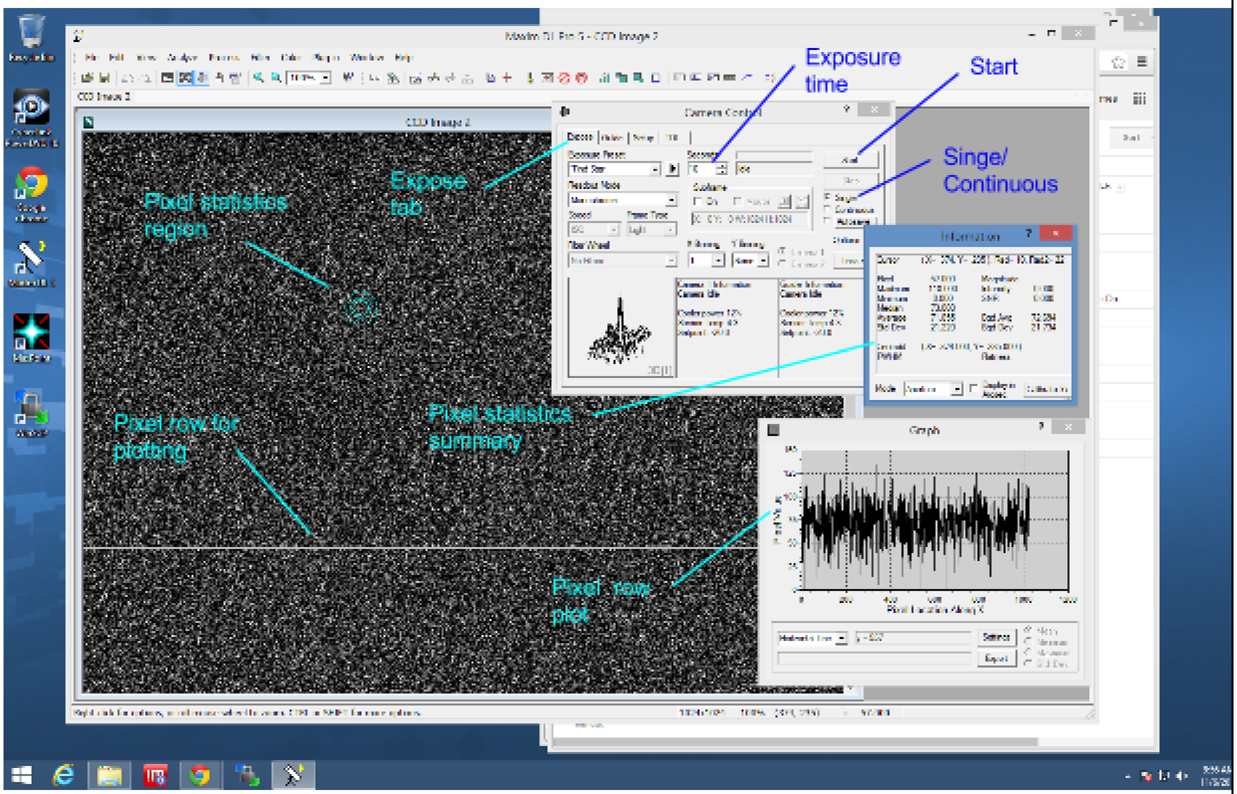

Figure 3: The exposure control window and some pixel statistics tools. The image displayed is a short dark exposure. The pixel statistics window and plotting tools are also open.

The exposure shown in Fig. 3 is effectively a dark because the calibration sources are turned off.

Figure 4 shows a 2-second exposure with the continuum lamp (quartz halogen) turned on. Each bright horizontal line in the CCD image is a different diffraction order from the echelle grating. The order of diffraction, m, changes by 1 between each adjacent order. The orientation of each echelle order is a function of m, so only one order can be aligned parallel to the CCD rows.

It is also evident from Fig. 4 that the echelle order separation is a function of m, with orders crowding together at the top of the image. The distinctive pattern of orders shown in Fig. 4: close together at the top; more widely spaced at the bottom indicate the direction of increasing wavelength. The tilt of each echelle order also reveals which is the red and which is the blue end, and hence the wavelength direction within that order.

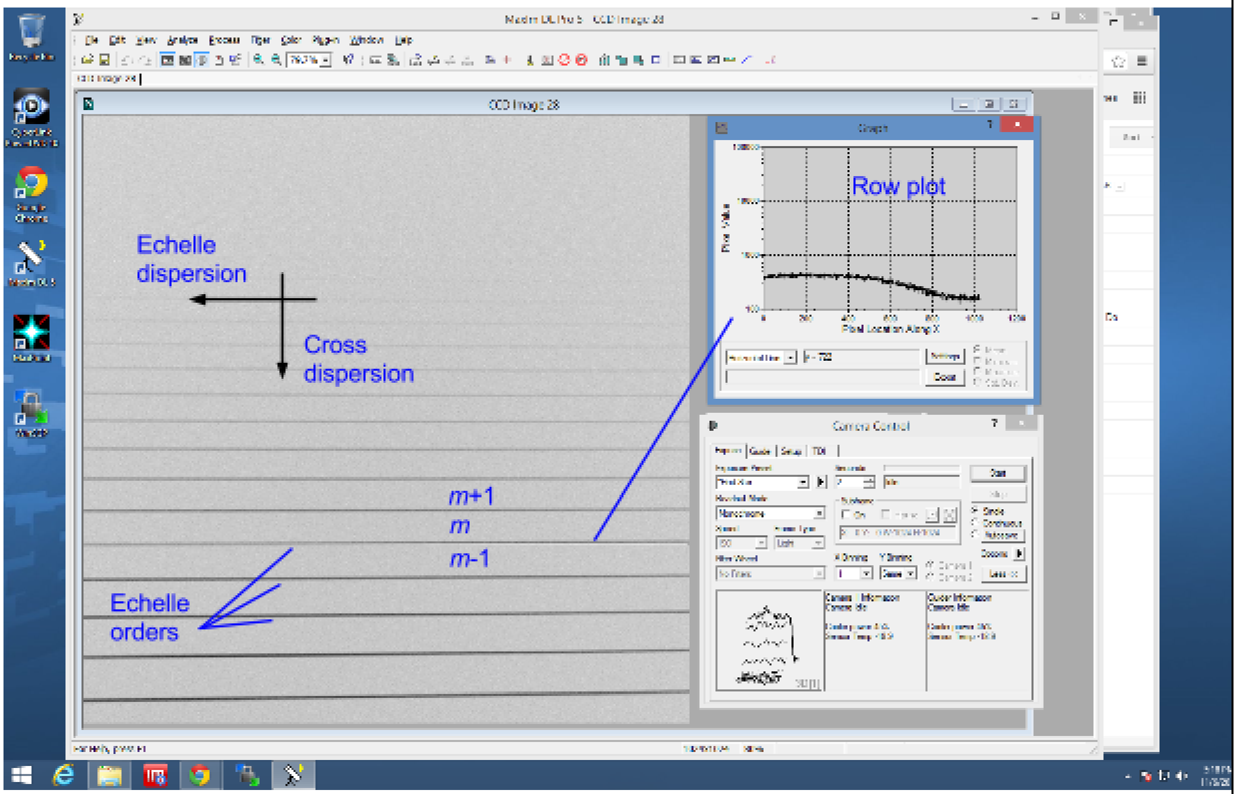

Figure 4: An exposure (2 s) showing the spectrum of a quartz halogen lamp. Each horizontal streak is an echelle-grating diffraction order. The color map is inverted: white is dim; black is bright. The dispersion directions of the echelle grating and the cross disperser are show.

The next figure (Fig. 5) shows the spectrum of a Ne lamp. Initially the image may appear to be a random collection of spots. However, on closer inspection it is clear that the spots delineate the same set of horizontal echelle orders that are present in Fig. 4. The pattern has hard to discern because the Ne lines do not occur at uniform intervals and some echelle orders are represented by only one or two prominent Ne lines.

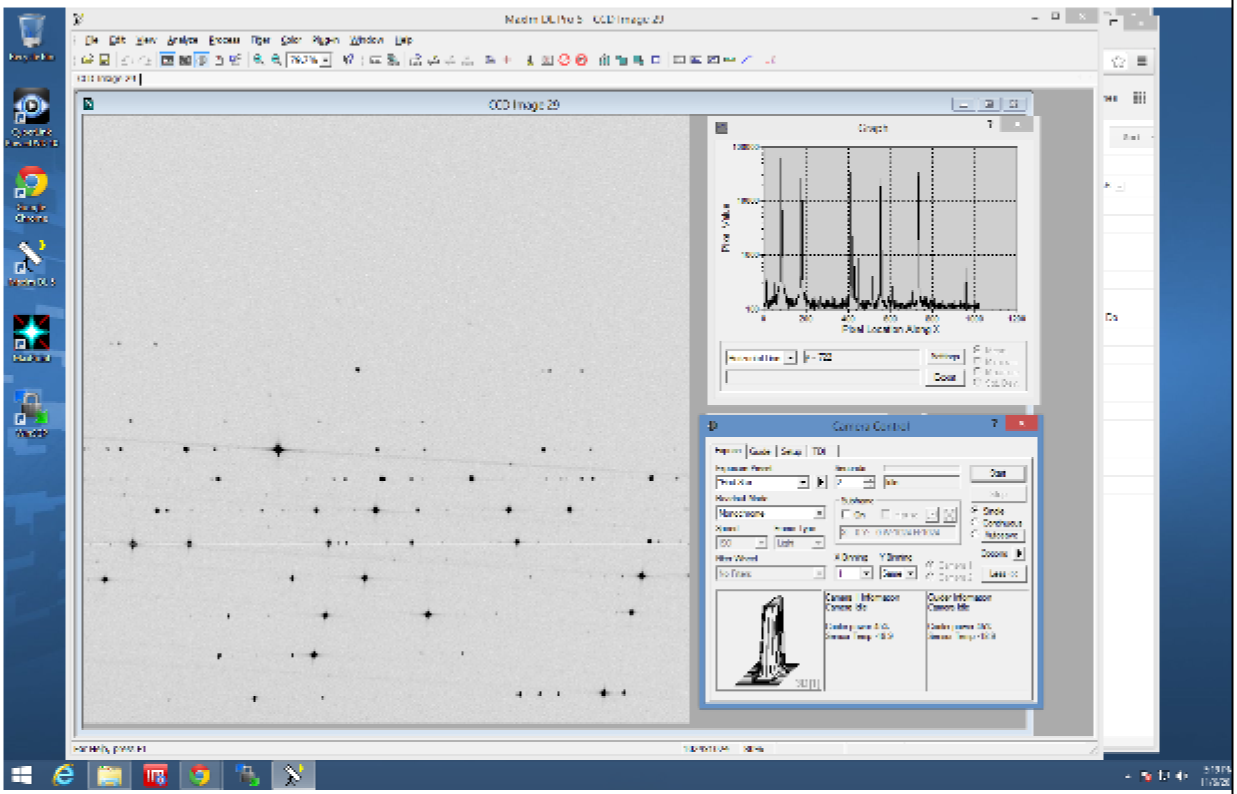

Figure 5: A 2 s exposure of the neon lamp showing approximately 50 bright Ne lines.

The final figure (Fig. 6) in this section shows the “Autosave” option that can be accessed from the “Expose” tab. This setting is important because it can be used to take sequences of images, e.g., for the solar scan this can be configured to automatically save one image after another without having to click the “Start” button for each new picture.

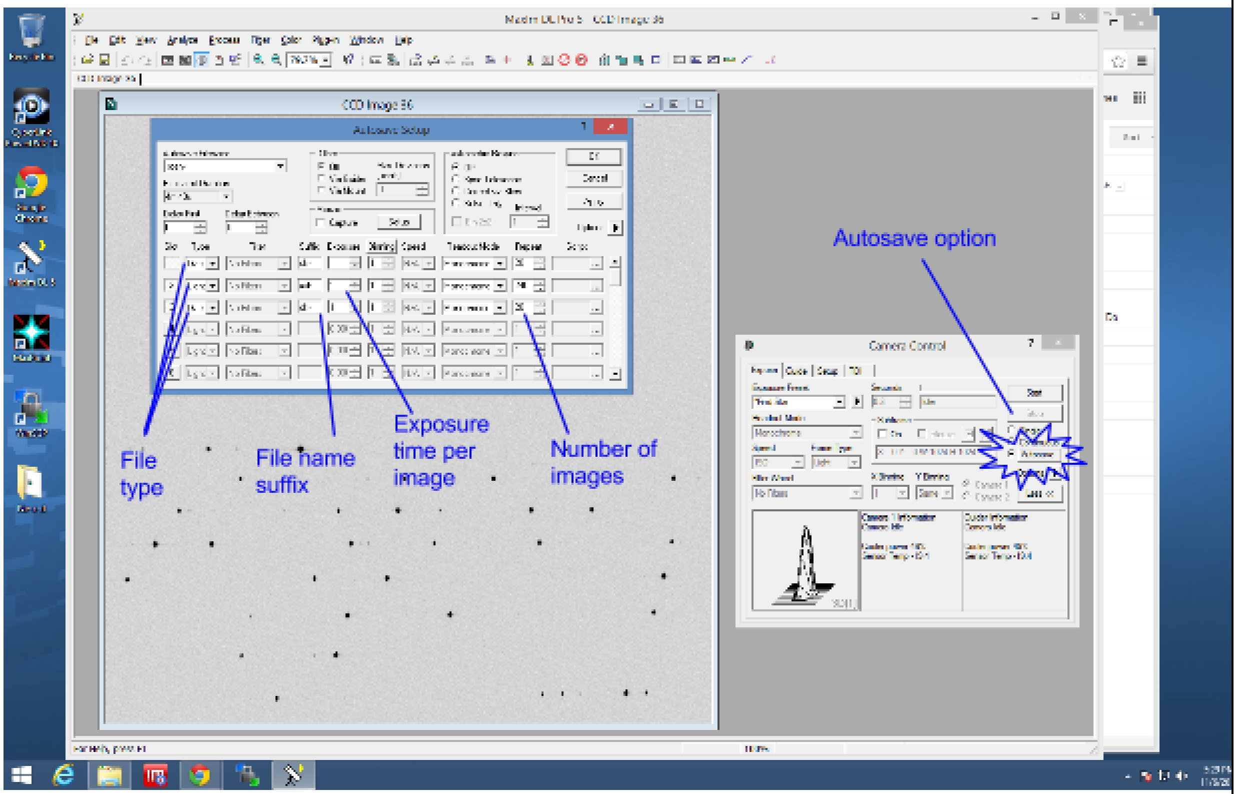

Figure 6: The "Autosave" option from the "Expose" tab allows sequences of images to be collected without human intervention. This example takes 20 darks (1s), followed by 240 regular exposures (1s), followed by another 20 darks (1s).

3. Operating the CCD Camera and Calibration Lamps

The first step is to turn on the CCD Camera. You can reach the web-controlled power switch (see Fig. 7) from

http://136.152.226.219 or ugspec2.astro.berkeley.edu

Access from outside the ugastro subnet is blocked by the firewall. The username is written on the switch and password is the regular user password for the lab. The CCD power (Power4) and the calibration lamps are all controlled via this interface.

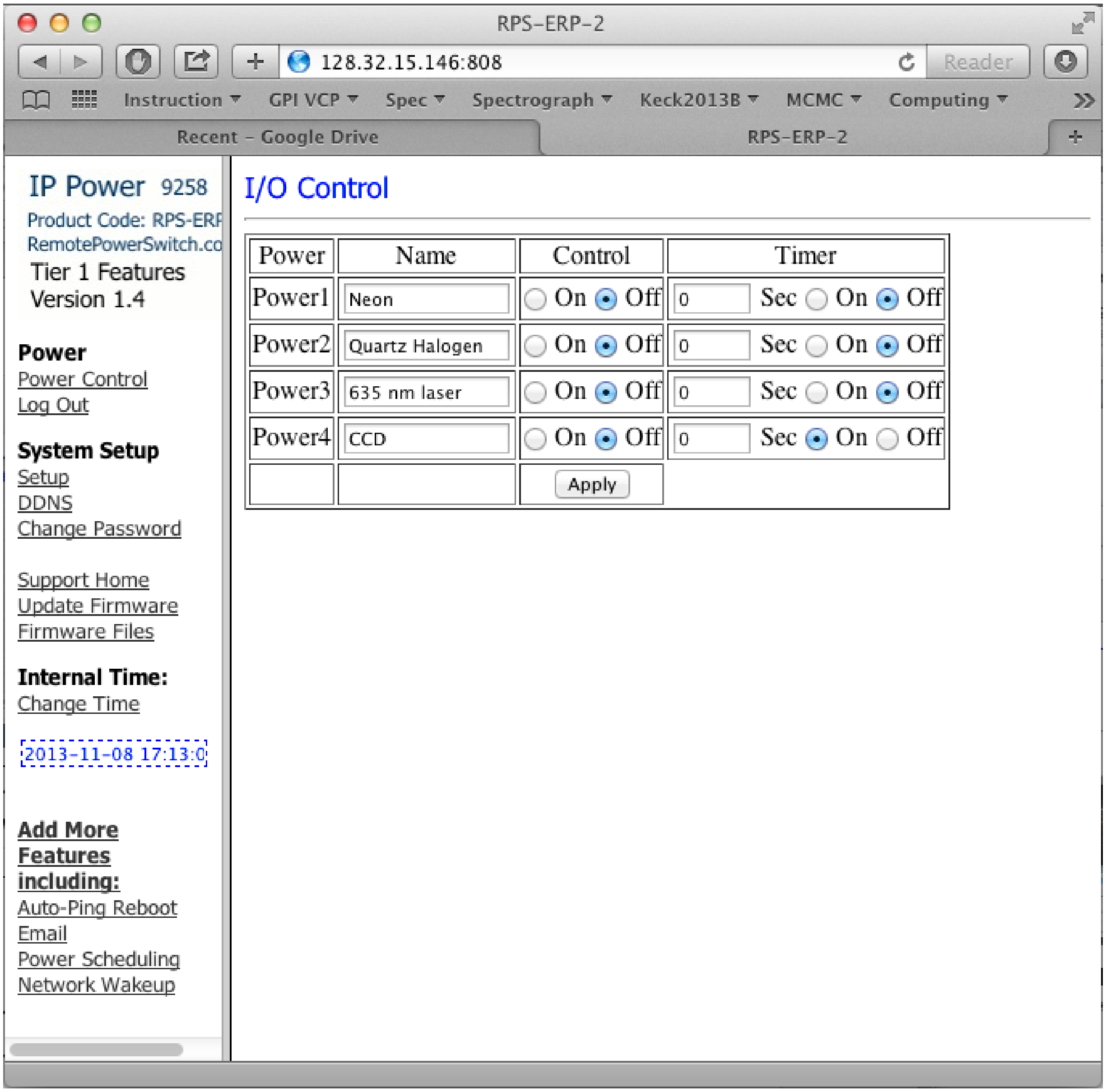

Figure 7: Remote control of the CCD power and the calibration lamps is enable via a web interface to a power strip. To activate select the state and click apply.

3.1. Access the CCD Controller Software

1. Start Nomachine Remote Desktop:
   a. On a lab workstation, run: /usr/NX/bin/nxplayer;
   b. Read the explanation screens and click "Continue" until you reach the connection screen;
   c. Enter "z" in the white address field and click on the lightning bolt (Quick Connect) icon;
   d. Enter the username and password for the lab account and click "OK";

    e. Read the explanation screens and expand the desktop as you prefer and click "OK".
2. Run the Software:
    a. On the remote desktop, double click on the "MaximDL 5" icon.

3.2. Finishing Up

1. On the remote desktop in the Maxim DL Camera Control Window, select Setup>Disconnect;
2. Exit Maxim DL software (agree to disconnect camera if not done previously…); and
3. Turn off all lamps and the CCD power.

3.3. Close Nomachine Session

1. In the remote session window, use CTRL+ALT+0 or click on the "peel back" upper right hand corner;
2. In the Nomachine control panel, select "Connection";
3. Click "Disconnect"; and,
4. Close Nomachine window.

If no one else will be using the CCD camera, check again to make sure that the CCD power is turned off.